

Ideas for Class Projects

M392C: Topics in Geometry and Physics

October 9, 2009

Here are some ideas to get you started on projects. But these are only suggestions; I encourage your suggestions and I welcome any topic in this broad area.

You may work individually or with a partner. The output of the project is a paper, which is due December 1 at the beginning of class. Please bring in two copies if there are two authors. We will permute the papers and you will make comments on one of your classmate's papers to the author. Those comments are due to the author by December 4. Then you have until the end of the day December 7 to bring me a final version of your paper. Please also send me an electronic copy so I can post the papers on the web to share with your classmates.

You should choose a topic by October 22. You need to come visit during office hours to discuss your topic with me.

What follows is a fairly random list of papers to start your thinking. Again, you are encouraged to find your own topics and papers. You can start that process by talking to me about some vague ideas or directions and I may make suggestions.

Singer, I. M., *The geometric interpretation of a special connection*. Pacific J. Math. 9 (1959) 585–590.

Moser, Jürgen, *On the volume elements on a manifold*, Trans. Amer. Math. Soc. 120 (1965) 286–294.

Kostant, Bertram, *Quantization and unitary representations. I. Prequantization*. Lectures in modern analysis and applications, III, pp. 87–208. Lecture Notes in Math., Vol. 170, Springer, Berlin, (1970).

Chern, Shiing Shen; Simons, James, *Characteristic forms and geometric invariants*. Ann. of Math. (2) 99 (1974), 48–69.

Hitchin, Nigel, *Compact four-dimensional Einstein manifolds*. J. Differential Geometry 9 (1974), 435–441.

Atiyah, M. F.; Hitchin, N. J.; Singer, I. M., *Self-duality in four-dimensional Riemannian geometry*. Proc. Roy. Soc. London Ser. A 362 (1978), no. 1711, 425–461.

Schoen, Richard; Yau, Shing Tung, *On the proof of the positive mass conjecture in general relativity*. Comm. Math. Phys. 65 (1979), no. 1, 45–76.

Atiyah, M. F., *Convexity and commuting Hamiltonians*. Bull. London Math. Soc. 14 (1982), no. 1, 1–15.

- Guillemin, V.; Sternberg, S., *Convexity properties of the moment mapping*. Invent. Math. 67 (1982), no. 3, 491–513.
- Uhlenbeck, Karen K., *Connections with L^p bounds on curvature*. Comm. Math. Phys. 83 (1982), no. 1, 31–42.
- Atiyah, M. F.; Bott, R., *The Yang-Mills equations over Riemann surfaces*. Philos. Trans. Roy. Soc. London Ser. A 308 (1983), no. 1505, 523–615.
- Donaldson, S. K., *An application of gauge theory to four-dimensional topology*. J. Differential Geom. 18 (1983), no. 2, 279–315.
- Witten, Edward, *Supersymmetry and Morse theory*. J. Differential Geom. 17 (1982), no. 4, 661–692 (1983).
- Atiyah, M. F.; Bott, R., *The moment map and equivariant cohomology*. Topology 23 (1984), no. 1, 1–28.
- Kirwan, Frances Clare, *Cohomology of quotients in symplectic and algebraic geometry*. Mathematical Notes, 31. Princeton University Press, Princeton, NJ, 1984.
- Fefferman, Charles; Graham, C. Robin, *Conformal invariants*. The mathematical heritage of lie Cartan (Lyon, 1984). Astrisque 1985, Numero Hors Serie, 95–116.
- Quillen, Daniel, *Superconnections and the Chern character*. Topology 24 (1985), no. 1, 89–95.
- Hitchin, N. J., *The self-duality equations on a Riemann surface*. Proc. London Math. Soc. (3) 55 (1987), no. 1, 59–126.
- Floer, Andreas, *Morse theory for Lagrangian intersections*. J. Differential Geom. 28 (1988), no. 3, 513–547.
- Witten, Edward, *Quantum field theory and the Jones polynomial*. Comm. Math. Phys. 121 (1989), no. 3, 351–399.
- Candelas, Philip; de la Ossa, Xenia C.; Green, Paul S.; Parkes, Linda, *A pair of Calabi-Yau manifolds as an exactly soluble superconformal theory*. Nuclear Phys. B 359 (1991), no. 1, 21–74.
- Kontsevich, Maxim, *Intersection theory on the moduli space of curves and the matrix Airy function*. Comm. Math. Phys. 147 (1992), no. 1, 1–23.
- Taubes, Clifford Henry, *The Seiberg-Witten invariants and symplectic forms*. Math. Res. Lett. 1 (1994), no. 6, 809–822.
- Witten, Edward, *Monopoles and four-manifolds*. Math. Res. Lett. 1 (1994), no. 6, 769–796.

Kontsevich, Maxim, *Homological algebra of mirror symmetry*. Proceedings of the International Congress of Mathematicians, Vol. 1, 2 (Zürich, 1994), 120–139, Birkhuser, Basel, 1995.

Weinstein, A., *The symplectic structure on moduli space*. The Floer memorial volume, 627–635, Progr. Math., 133, Birkhuser, Basel, 1995.

Segal, Graeme, *The definition of conformal field theory*. Topology, geometry and quantum field theory, 421–577, London Math. Soc. Lecture Note Ser., 308, Cambridge Univ. Press, Cambridge, 2004.

Atiyah, Michael, *Topological quantum field theories*. Inst. Hautes Études Sci. Publ. Math. No. 68 (1988), 175–186

Witten, Edward, *Topological quantum field theory*. Comm. Math. Phys. 117 (1988), no. 3, 353–386.

Guillemin, Victor; Sternberg, Shlomo, *The moment map and collective motion*. Ann. Physics 127 (1980), no. 1, 220–253.

Bott, Raoul *Critical point theory in mathematics and in mathematical physics*. Turkish J. Math. 21 (1997), no. 1, 9–40.

Freed, Daniel S., *Classical Chern-Simons theory. I*. Adv. Math. 113 (1995), no. 2, 237–303.

Jeffrey, Lisa, *Symplectic forms on moduli spaces of flat connections on 2-manifolds*. Proc. Georgia Intl. Topology Conference (Athens, GA, 1993), W. Kazez, ed., AMS/IP Studies in Advanced Mathematics 2 (1997) (Part 1) 268–281.

You may want to choose some material from one of the following books:

Quantum fields and strings: a course for mathematicians. Vol. 1, 2. Material from the Special Year on Quantum Field Theory held at the Institute for Advanced Study, Princeton, NJ, 1996–1997. Edited by Pierre Deligne, Pavel Etingof, Daniel S. Freed, Lisa C. Jeffrey, David Kazhdan, John W. Morgan, David R. Morrison and Edward Witten. American Mathematical Society, Providence, RI; Institute for Advanced Study (IAS), Princeton, NJ, 1999.

Hori, Kentaro; Katz, Sheldon; Klemm, Albrecht; Pandharipande, Rahul; Thomas, Richard; Vafa, Cumrun; Vakil, Ravi; Zaslow, Eric, *Mirror symmetry*. With a preface by Vafa. Clay Mathematics Monographs, 1. American Mathematical Society, Providence, RI; Clay Mathematics Institute, Cambridge, MA, 2003. xx+929 pp.

Katz, Sheldon, *Enumerative geometry and string theory*. Student Mathematical Library, 32. IAS/Park City Mathematical Subseries. American Mathematical Society, Providence, RI; Institute for Advanced Study (IAS), Princeton, NJ, 2006.